Geometric Control of Magnon–Photon Coupling in Attached Split-Ring Resonator Cavities

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We present the design, optimization, and numerical analysis of a planar attached split-ring resonator (ASRR) cavity integrated with yttrium–iron–garnet (YIG) structures of different geometries to investigate magnon–photon coupling. The influence of magnetic element shape on ferromagnetic resonance (FMR) and coupling strength is studied in compact, chip-scale systems under identical in-plane bias conditions. Three YIG geometries—a full ring, a half ring, and a thin disk—are compared. The ASRR cavity is optimized using full-wave electromagnetic simulations by varying the inter-ring spacing, gap width, substrate thickness, and dielectric permittivity, resulting in a quality factor of approximately $Q \approx 190$ at a resonance frequency of 5.48 GHz.Ferromagnetic resonance fields for the ring and half-ring geometries are determined using a linearized Landau–Lifshitz–Gilbert (LLG) eigenvalue formulation that includes exchange and demagnetizing fields, while the resonance of the thin disk is validated using the Kittel relation. When integrated with the ASRR cavity, all geometries exhibit clear avoided crossings in the transmission spectra, confirming strong magnon–photon coupling. The full-ring geometry yields a coupling strength of $g = 50$ MHz with a cooperativity of $C \approx 25.2$, while the half-ring geometry shows an enhanced coupling strength of $g = 70$ MHz but a reduced cooperativity of $C \approx 20.5$ due to enhanced edge demagnetization effects. The disk geometry couples at lower bias magnetic fields, approximately 127–135 mT, and exhibits the strongest interaction, with a coupling strength of $g = 145$ MHz and cooperativity of $C \approx 47$, enabled by improved microwave–magnetic field overlap. These results demonstrate that magnetic geometry plays a crucial role in controlling coupling strength and coherence in planar magnon–photon systems and provide design guidelines for scalable hybrid magnetic devices.